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XI. *Supplementary Researches on the Direction and Mode of Propagation of the electric Force, and on the Source of electrical Development.* By GEORGE J. KNOX, Esq., A. M., M. R. I. A.

Read May 25th, 1840.

HAVING in my former paper* described some experiments which proved that water and phosphorus convey a current of electricity through their substances, while metals convey the current along their surface, and feeling anxious to discover some general law regarding the direction of propagation in liquid and solid bodies, I have continued the investigation to fluids ; not only those which convey the feeble current of the voltaic pile, but to others which require the high intensity of the electrical machine ; and although the experiments be few, yet I think that they may be considered to be sufficient to establish the law regarding fluids, that they convey through their substance in all directions alike ; an opinion which one would be inclined to adopt previous to experiment, from considering the difference between the nature of liquid and solid bodies, the one having their particles chained down by powerful affinities, which no ordinary electrical force can overcome, while the other, from the perfect mobility of their particles, allow the electric state to be induced upon them with equal facility in one direction as well as another.

That there exists no regular law with regard to solids, appears from the Researches of Dr. Faraday (XI. and XIV. Series), in which he shows, that the lines of induction do not pass *through* metallic bodies (1221), (affording a corroborative proof to mine that they do not convey through their substance), while several solid bodies, such as shell-lac, sulphur, &c. (1228, 1308, 1309, 1310), allow the inductive force to pass through them with greater facility even than air.

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* Tran. R. I. A., vol. xix. p. 147 ; Phil. Mag. vol. xvi. p. 185.

EXPERIMENTS.

The bent glass tube which I employed in my former experiments having been filled alternately with muriatic acid, hydriodic acid, sulphate of copper, and muriate of ammonia, and the circuit being completed by a current from a sustaining battery of one pair of elements, the same law was found to subsist as when water and phosphorus were employed, i. e. that the current passed through their substance and not along their surface. The same likewise took place when the tube was filled with fused chloride of tin, which conducts by electrolysis, and fused periodide of mercury, which conducts by conduction.

To determine whether this law with regard to liquids which convey a galvanic current subsists when non-conducting fluids are employed, I filled the tube alternately with alcohol, naphtha, oil, fused lard, bees' wax, and resin, and having connected one of the insulated wires with the ground, I connected the other with an insulated brass ball, fixed at the distance of four-tenths of an inch from the prime conductor, of a nine inch electrical machine.

ALCOHOL OR NAPHTHA.

When the platinum wires were immersed in the legs of the bent tube until their extremities were placed at the distance of five inches, ten sparks passed in one revolution of the plate; when at two feet distance, eight sparks; when at four feet distance, six sparks.

OIL.

At the distance of five inches, seven sparks passed in one revolution of the plate; at the distance of two feet, four sparks passed; and at the distance of four feet, two sparks passed in one revolution.

FUSED LARD.

At the distance of five inches, two sparks passed in one revolution of the plate; at the distance of two feet, one spark in one revolution; at the distance of four feet, one spark in three revolutions.

BEES' WAX.

At the distance of five inches, one spark passed in one revolution of the plate; at the distance of two feet, one spark in one revolution and a half; at the distance of four feet, one spark in two revolutions.

RESIN.

At the distance of five inches, one spark passed in one revolution of the plate; at the distance of two feet, one spark in two revolutions; at the distance of four feet, one spark in two and three-fourth revolutions.

These latter substances begin to conduct when in the viscid state, and the conducting power increases up to the boiling point.

SOURCE OF ELECTRICAL DEVELOPMENT.

Before reconsidering the source of electrical development, I shall briefly mention the arguments which may be brought forward against the emission, and in favour of the vibratory theory, the former supposing a transference of electricity from particle to particle, the latter assuming that the atoms of matter are encircled with ethereal atmospheres, the atoms of which can oscillate within certain distances. The arguments in favour of this latter theory, independent of such as the mathematician may bring forward, rest upon the hypothesis proposed by Sir H. Davy,* "which, after a lapse of twenty years, continued, as it was in the beginning, to be the guide and foundation of all his researches;" a theory now almost universally received as established—that chemical affinity is an electrical phenomenon, and that the entire subject of chemistry is an illustration of that primary law of electricity, the attraction of oppositely electrical bodies. If the electric forces which cause the attraction of bodies be definite, as they are, being their atomic numbers, how can this be consistent with a theory which supposes that the electricity leaves the particles, allowing them at one moment to contain more electricity than at another, and, consequently, a higher affinity, and a different atomic number?

When two atoms are brought into contact, their electrical ethers, being disturbed, cause a disturbance to take place in the electrical ethers of adjacent atoms, which disturbance should increase until it arrives at a maximum, when combination takes place. The same may be said of the compound atoms or molecules, of the compound molecules or particles, and of the compound particles or bodies *en masse;* and that such a development of electricity by contact of the *latter* does take place, the original experiments of Volta, together with the late experiments of Fechner and Peclet, have fully established. Fechner[*] has proved (having shown that the same experiment was incorrectly tried by Delarive), that when potassium, or sodium, are brought into contact with platinum, electrical development takes place without chemical action. Peclet[†] has proved that electrical excitation is caused by the contact of platinum and gold, *where chemical action could not take place*. In support of the opposite opinion is the experiment of Delarive,[‡] who found, that when chlorine gas is passed through an insulated copper tube, the condenser exhibits electrical development, which, he remarks, decreases when chlorine, unmixed with atmospheric air, is employed, and also when the chemical action between the chlorine and copper is violent; circumstances which admit of a simple explanation by the contact theory, according to which the air receives an electrical charge from the chlorine while in contact with the copper, which charge so much of the gas as *combines* with the copper loses. The same explanation may be given to the experiments of Peclet,[§] who has satisfactorily shown that the presence of moisture is necessary in order that the oxidation of the amalgam on the rubber of an electrical machine should develope electricity, the aqueous vapour in this case receiving the charge. *Experiments*, then, having proved, that contact and not chemical action causes the development of electricity, the question arises, how are we to explain the phenomena? When two atoms unite, it is difficult to avoid the conclusion, that the compound atom (molecule) must have oppositely electrical surfaces. Two such polarized molecules approaching cause a disturbance to take place in the electrical ether, which disturbance is propagated by induction to a distance; but when the molecules approach sufficiently near to combine, the two oppositely electrical surfaces of one molecule coming in contact with the two oppositely electrified surfaces of the other, no development of electricity can take place, the electrical states becoming completely disguised; and such a supposition is borne out by every fact in crystallography, which shows that the molecules have poles. The particles being compound molecules should have poles likewise; and when they unite, or chemical combination takes place, there should be no development of electricity; and, consequently, when oxygen unites with zinc (as in the galvanic battery) no development of electricity should take place from their union; but the hydrogen, whose positive pole had been previously united with the negative pole of the oxygen, should induce negative electricity upon the oxide, while the negative pole should induce positive electricity upon the next particle, and so on to the platinum plate.

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* Bakerian Lecture, 1807–1826.

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[*] Phil. Mag. vol. xiii. 1838.

[†] Annales de Chimie, tom. lxxi. p. 80.

[‡] Bib. Univer. N. S. tom. iii.

[§] Annales de Chimie, tom. lxxi. p. 83.

The greater the number of particles of hydrogen inducing electricity upon the platinum plate, the greater, of course, the quantity of electricity induced upon that plate; the number of particles of hydrogen being the measure of the quantity, whether it was oxygen, chlorine, iodine, or bromine, with which the hydrogen may have been previously in combination; and that such is the case is proved by experiment. That alternate recombinations and decompositions take place has been shown by Grothhus and Faraday.

How beautiful is the analogy which subsists between statical and voltaic electricity when the contact theory is adopted! By friction (lateral contact) between silk and glass opposite electrical states are induced upon each. By the contact of zinc with a dry acid, or alkali, opposite states are induced upon each. When the plate of the electrical machine is put in motion, the prime conductor receives a charge whose intensity is directly as the non-conducting or insulating nature of the glass, and as the distance between the collecting forks and the rubber when the axis is made of glass. When the zinc is placed in contact with the acid, or alkali in *solution*, the charge is allowed to pass from the zinc to the platinum, being in this case a charge by induction, as in the former case it was one by convection; and the intensity varies as the insulating state of the solution, and as the distance between the platinum and zinc, as is proved by the experiments of Delarive,* which show that the water battery charges to a higher intensity than the acid battery, although it takes a longer time than the latter to charge to a given amount. Again, when a small electrical machine is rotated rapidly, while a larger one is rotated slowly, the former will charge to a *given intensity* in a shorter time than the latter, although it never can rise to an *equal intensity*. So in the acid and water batteries, the former, owing to the rapidity of alternations of induction and equilibrium, charges to a *given intensity* in a shorter time than the latter, yet still it never can rise to an *equal intensity*. Similarly may be explained why, when two metals in a solution form a closed circuit, whatever increases the chemical action upon one more than upon the other, increasing the rapidity of alternate states of induction, produces a charge in a shorter time; and this takes place not only when two different metals are employed, but also, when plates of the same metal being used, a difference of polish or a difference of heat applied alters the chemical action upon one plate more than upon the other. A further analogy is faintly borne out by the following experiments, which may lead to an explanation of some curious facts regarding the alternate increase and decrease of intensity in the voltaic pile, dependent upon the number of alternations, as observed by Delarive* and others. Having connected, by means of insulated copper wires, the insulated conductors of an electrical machine, with two insulated brass balls, the spark that passed between the two balls measured one-fourth of an inch. When the insulated negative conductor of this machine was connected with the insulated prime conductor of another similar one, and its insulated negative conductor with one of the brass balls, and the two machines rotated simultaneously, the length of the discharging spark was increased to one-half; with three electrical machines similarly arranged, the length of the spark which passed was one-third; with four, it returned to one-half; beyond this number no regularity in the length of the discharging sparks was observable. The quantity in the electrical machine increases with the number of collecting forks, when the rubbers and forks are disposed in such a manner, that the latter can receive the greatest quantity of electricity from the excited glass; so in the voltaic pile, the quantity is as the number of particles of hydrogen set free against the surface of the platinum.

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* Bib. Univer. tom. iv. p. 360.

The effect which a current of electricity, considered to be a row of particles whose oppositely electrified surfaces are ranged in the same direction, undergoing alternate states of induction and equilibrium, produces upon contiguous particles, should be to induce in them oppositely electrified surfaces, which, in undergoing alternate states of induction and equilibrium, should obviously give rise to a current of electricity in an opposite direction,—and this is agreeable to fact.

To afford an explanation of magnetism, considered as an electrical phenomenon, no theory as yet proposed is adequate. That of Ampére (although exceedingly beautiful) is yet all but physically impossible, for how can we suppose that when the electrical current which magnetizes a steel bar ceases, the electricity in the bar continues to revolve round the particles of the steel? Does not the marked difference between iron and other metals, and between steel and soft iron in the same metal, show that magnetism (if electrical) must be a case of statical electricity? What arrangement of electrified bodies may produce such a state of statical power may possibly be within the reach of experiment; but to determine the condition of the electrical ether in a bar of steel, is a question which, as it regards the mutual actions of systems of attracting and repelling points, being far beyond the reach of experiment, requires for its solution a higher, more elegant, and more comprehensive instrument of research, mathematical analysis.

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* Bib. Univer. Tom. iv. p. 360.